INSTITUTE OF PAPER CHEMISTRY
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INVESTIGATION OF THE USE OF WASTE SULFITE-POLYVINYL ALCOHOL ADHESIVE AS A CORRUGATING ADHESIVE

Project 1748

Progress Report One

to

CORRUGATING ADHESIVE GROUP

March 8, 1954

THE INSTITUTE OF PAPER CHEMISTRY

APPLETON, WISCONSIN

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During the summer of 1953 the Consolidated Water Power and Paper Company initiated a preliminary project at The Institute of Paper Chemistry directed towards evaluating The Gummed Products Company's patented adhesive for use in the production of corrugated board. The U. S. patents concerned are

No. 2,443,889 June 22, 1948 - D. S. Bruce and H. L. Heise

No. 2,544,585 March 6, 1951 - D. S. Bruce and H. L. Heise

both of which are assigned to The Gummed Products Company, Troy, Ohio. The broad claim represented by these patents is "an adhesive, the active adhesive agent therein consisting of from 3 percent to 10 percent of polyvinyl alcohol and from 97 percent to 90 percent of a concentrate of waste sulphite liquor containing lignosulphonic acid, proportions being on a dry basis."

The results of this preliminary investigation indicated that the adhesive as used did not have sufficient "initial tack" to serve satisfactorily as an adhesive for producing corrugated board on the single-face section of a corrugator. Upon completion of the above preliminary work, the results were reviewed with representatives of Consolidated Water Power and Paper Company. Also present at this meeting, upon the invitation of Consolidated, were representatives of Marathon Corporation, Rhinelander Paper Company, and The Gummed Products Company. Upon discussion of the conclusions reached in the preliminary investigation carried out for Consolidated Water Power and Paper Co., it was agreed that this next phase of the program would be divided towards improving the "initial tack" of the adhesive, and that the project should be sponsored by the several interested companies. In keeping with the above recommendation the phase of the work reported herein was initiated as a co-operative project under the sponsorship of the following five interested companies:

1. Consolidated Water Power and Paper Company
2. Crown-Zellerbach Corporation
3. International Paper Company
4. Marathon Corporation
5. Rhinelander Paper Company

At the meeting wherein it was decided that this work should best proceed as a group project, it was agreed that the initial phase of the work should be directed toward an effort of limited scope to improve the initial tack of the adhesive by means of increasing the solids content. It was hoped that a marked increase in tack of the adhesive might be accomplished under these conditions by the removal of a small amount of water from the adhesive either through adsorption by the components or by evaporation.

It was agreed that for the initial phase the study should be limited to the following materials:

1. International Paper Company's Bindarene Flour (not mixed with polyvinyl alcohol.)
2. Polyvinyl alcohol, No. 52-22.
3. Clay Huber X-43

The general approach decided on was to vary the amount or proportions of the ingredients to get as high a solids content as possible in keeping with runability on the single-facer. If the viscosity was too great, this was to be cut back with a fluidizing agent.

Corrugated combined board is normally composed of three components--i.e., single-face liner, corrugated medium, and double-face liner. In the manufacture of corrugated board the fabrication operation may be considered as taking place in two major but sequential steps, each step involving, among other things, the application of adhesive to the tips of the corrugated medium subsequently followed by union with the respective facing or liner. Although it is common practice to use the same adhesive at each glue station, the requirements vary considerably because of the features of the operation; however, the ultimate objective is the same--namely, to securely bond the facings--i.e., single- and double-face liners--securely to the corrugated medium. The majority of corrugated board is fabricated with what is known as regular adhesive; that is, they are not intended as a water-resistant adhesive. The most common regular adhesives are starch, sodium silicate, silicate-clay and more recently the so-called "three-way adhesive" which is a formulation containing sodium silicate, starch and clay.

The first major step in the fabrication of corrugated board is the single-face operation. This operation consists of fluting the corrugating medium by passing the medium between heated metal rolls of proper contour; applying adhesive to the exposed tips of the thus-formed flutes while the medium is contiguous with the bottom corrugating roll; and finally the bonding of the single-face liner and corrugating medium in a pressure nip comprised of the bottom corrugating roll (contiguous with corrugated medium) and a smooth heated metal pressure roll backing up the single-face liner. The emergent board is known as single-faced board. The sequence of operations in corrugating necessitates that when the single-faced board emerges from the pressure or combining nip, the adhesive must have developed sufficient bonding between the two fibrous components to hold them in juxtaposition during subsequent operations and until the final bonding strength has developed. Consequently, the adhesive used at the single-face glue station must meet rather stringent requirements. These requirements are probably more readily appreciated when one keeps in mind that in A-flute board only a very small portion (approximately 1/3) of the total surface area is bonded. In addition, at the very modest speed of 300 feet per minute the time lapse between the application of the adhesive to the flute tips and the initial bonding of the single-face liner is only about 0.15 seconds.

The second major operation in the fabrication of double-faced corrugated board is the adherence of the second facing or liner. This is done in what is known as the double-backing or double-facing operation. The essential steps in this operation involve the application of adhesive to the tips of the exposed flutes, the subsequent union of the adhesive coated single-face board and the double-face liner, the setting of the adhesive by sliding (conveyed by belt against top side) the board over a series of steam tables (double-face liner against steam tables) and then conveyed between belts through a "cooling" section. In the operation just described the pressure holding the board against the steam table must by necessity be kept very low; however, the length of a normal hot-plate and cooling section is such that the time lapses between the application of the adhesive and the emergence of the board from this section on a modern corrugator is in the neighborhood of 18 seconds when operating at a modest speed of 300 feet per minute. On the basis of the above set-up times, it may be calculated that the time for development of at least initial bond on the double-face side is approximately 120 fold that on the single-face side.

As previously mentioned, the adhesives normally used today for the bulk of corrugated board producers are starch, sodium silicate, silica-clay and three-way adhesive.

Sodium silicate and silica-clay adhesives depend upon their ability to wet readily the surface of the board to be combined and for their setting upon the large rise of viscosity occurring when relatively small amounts of water are withdrawn from the adhesive either by absorption into the board or by evaporation. An adhesive of ratio $SiO_2 \cdot Na_2O$ of 3.3 to 1 can be made to set with a water loss of about 5% of the adhesive weight.

The particular application of present day starch is somewhat different from its early use as a paste. This current method of bonding corrugated board with starch was developed and patented by the Stein-Hall Company in 1934 and is known as the Stein-Hall Process. In brief, this process consists in applying a suspension or dispersion of raw starch to the tips of the flutes of the corrugated medium and utilizing the heat in the corrugated medium to gelatinize the starch to form the adhesive, hence, it is gelatinization "in situ". In actual practice a small percentage of the starch is gelatinized and used as a means of keeping the raw starch in suspension. In addition the gelatinization temperature is controlled by the use of alkalies. Inasmuch as the starch is applied in the ungelatinized state, it is possible to use a vastly higher solids content than would be possible with a dextrine adhesive.

The "three-way" adhesive is an attempt to combine the desirable qualities of all the adhesives. A lower viscosity silicate is used in this adhesive; however, the presence of the clay and starch plus heat impart the desirable flow properties. The presence of the lower viscosity silicate gives easier wetting; the clay, in combination with the water take up when the starch gelatinizes, gives a much faster initial bond. In the above adhesives, the initial bond is dependent on an increase in viscosity by removal of water or by the formation of a gel.

As previously mentioned, the objective of this study was directed towards the improvement of initial tack or bond by means of increasing the solids content of the adhesive. Basically the problem appears to be one of time to develop initial bond. It has previously been pointed out that the interval between the application of adhesive and the necessity for initial bonding is only a fraction of a second. Naturally, there are other factors such as fluidity, final bond strength, etc., which need be considered. The approach was agreed upon because it was felt that the basic formulation develops its initial bond as a result of increased viscosity brought about by removal of water rather than by a gel phenomenon.

The approach used in this exploratory phase was to make up various formulations and test the effectiveness of each as a single-facer adhesive. This was done by making fabrication runs on the Institute's small single-face corrugator and noting the runability and degree of bonding obtained. The exploratory work was actually divided into two parts. The first part was primarily an attempt to bracket the desirable formulation, and as a consequence the formulations were more speculative than systematic. The second part was a more systematic investigation involving the study of only one variable at a time.

During the formulative meeting of the group, The Gummed Products Company suggested that it might be helpful to have Mr. Heise, one of the co-inventors of the adhesive, work with The Institute of Paper Chemistry on this project inasmuch as he was probably the one most familiar with the adhesive. As a result Mr. Heise spent considerable time in Appleton collaborating with the Institute on Part I. Needless to say, Mr. Heise was most helpful and the Institute is very grateful to Mr. Heise and The Gummed Products Company whose interest in this work made his visit possible.

GENERAL PROCEDURE

MATERIALS

As previously mentioned, the main ingredients of the adhesive were limited to the following:

1. Bindarene [International Paper Company (not mixed with polyvinyl alcohol.)]

2. Polyvinyl alcohol 52-22 (medium viscosity, approximately 88% hydrolysis).

3. Clay (Huber X-43)

The fibrous material used in the fabrication runs consisted of 42-lb. Fourdrinier kraft liner and 26-lb. semichemical corrugating medium. These materials were selected because they represent one of the largest tonnage combinations.

FABRICATION

The merits of each formulation as a corrugator adhesive at the single-facer was determined by making fabrication runs on the Institute's small laboratory corrugator using the liner and corrugating medium listed above. The same liner and medium were used throughout. The single-facer unit was operated under normal conditions which were standardized throughout the runs except that slight variations were tried where it was deemed advisable. The operating conditions used were as follows:

Temperature, °F.	
Top corrugating roll	310
Bottom corrugating roll	310
Pressure roll	320
Liner Preheater	335
Medium preheater	500 +
Adhesive Roll Clearance, inches	
Pick-up and transfer	0.20
Doctor roll	0.008 to 0.012

FORMULATIONS

Part I

The formulations tried in Part I were based on the work carried out by The Gummed Products Company. During this period of the work, Mr. Heise of The Gummed Products Company collaborated with the Institute. The proportions used in each trial in Part I are shown in Table I. In preparing the various formulations shown in Table I, the following procedure was used:

The polyvinyl alcohol was used as a 20% solution, except in Run No. 3 where it was added dry, and was prepared in the following manner: The polyvinyl alcohol was slowly added to the proper amount of tap water at room temperature with constant agitation and allowed to mix at room temperature for one hour. After the one-hour wetting-out period, the mixture was heated on a water bath to 180°F. (required approximately 30 minutes to reach 180°F.) with constant agitation. The polyvinyl alcohol and water mix was maintained at this temperature level until the polyvinyl alcohol was in solution. This normally required about 15 minutes at 180°F. The mixing vessel was weighed before and after heating and water was added to compensate for the evaporation which took place during the heating.

The compounding of the adhesive was carried out in a steam jacketed vessel, agitation being supplied by means of a Lightnin' mixer. In preparing each formulation, the clay was slowly added to the proper amount of water with constant agitation. In the two trials (No. 1 and 2) where sodium aluminate was used, the sodium aluminate was dissolved in the water before the clay was added. The sodium aluminate tended to increase

TABLE I

ADHESIVE COMPOSITION AND BONDING CHARACTERISTICS

Formula No.	Adhesive Composition*, parts						Adhesive Characteristics			
	Water	Clay	Bindarene	Polyvinyl Alcohol	Ahcowet	Urea	Solids, %	Temperature Applied, °F.	Viscosity, seconds	Bonding Characteristics
1[a]	524	100	100	6	1	10	32.9	126	21 at 126	Board not bonded at 50 f.p.m.
2[b]	324	100	100	6	7	--	41.2	170	**	Board not bonded at 50 f.p.m.
3[c]	170	50	150	6	1	10	56.1	200	18 at 200	Held board together at 50 f.p.m. but did not pull fibers.
4	170	50	150	6	1	6	55.6	100	53 at 100	Held board together at 50 f.p.m. pulled fibers only after board stood 15 minutes. Better than No. 3.
5	Formula 3 and 4 mixed together, 200 cc. H_3PO_4 added.						--	100	--	No bond at 50 f.p.m. Became too thick on cooling.
6	152	50	150	17	1	10	60.0	170	**	No bond at 50 f.p.m. Became too thick on cooling.
7	154	65	135	15	1	15	60.0	170	54 at 170	No bond at 50 f.p.m.
8	143	135	65	7	1	7	60.0	170	**	No bond at 50 f.p.m. Appeared too thick and too little cohesion.
9	143	65	135	7	1	7	60.0	170	41 at 170	Pulled fibers at 50 f.p.m. Did not hold at higher speed--i.e., 100 f.p.m.
10	160	135	65	15	1	14	59.0	170	**	No bond, appeared too thick and too much clay.
11[d]	159	80	120	10	1	7	57.8	170	54 at 170	Held board together at 50 f.p.m. but not as good as No. 9.
12	143	—	200	7	1	7	60.0	170	84 at 170	No bond, adhesive too brittle.
13	143	65	135	7	1	7	60.0	170	41 at 170	Repeat of No. 9 results not quite as good. Added water to give 34 sec. viscosity. Results slightly better.
14	89	65	135	7	1	55	74.7	170	--	No bond obtained.

* Weight basis.
** Too viscous to measure with Stein-Hall viscometer.

a 40 parts sodium aluminate added.
b 20 parts sodium aluminate added.
c Polyvinyl alcohol added dry. In all other formulations added as 20% solution.
d 254 g. calcium chloride added in adhesive pan while running. Did not mix well.

the viscosity or body of the adhesive. After the clay had been well dispersed and a smooth mix obtained, the Bindarene was slowly added while the mixture was being agitated. As soon as foam developed from the addition of the Bindarene, half the designated amount of Ahcowet was added. After the designated amount of Bindarene had been added (no noticeable change in viscosity), the mixture was heated to 180°F. (indirect). It generally required about 15 minutes to bring the temperature up to 180°F. When the temperature reached 180°, the polyvinyl alcohol solution was added slowly with agitation, the remaining amount of Ahcowet was added and the entire mixture agitated until a smooth mix was obtained. In those formulations (Runs 6, 7, 8 and 10) where the amount of water was insufficient to give adequate mixing of the clay, the Bindarene and clay were dry blended and then added to the water. As mentioned previously, the polyvinyl alcohol was added dry in Run No. 3. The dry polyvinyl alcohol was added in the same sequence as the polyvinyl alcohol solution; however, the mixture was heated to 200°F. and held for approximately 45 minutes to obtain solution of the alcohol.

Part II

The work carried out in Part II was designed to determine the change in adhesive characteristics, particularly initial bonding, resulting from varying the proportions of each ingredient in accordance with a set pattern. The work carried out in Part I was, through necessity, a more random approach in which the objective was to formulate an adhesive which would at least bond single-faced board at the slowest speed. Such a formulation could then be used as a reference in measuring progress. As will be shown later, the most promising formulation used in Part I was No. 9. Consequently this formula was used as the starting point for the work carried out in Part II. This phase consisted in varying the percentage solids (keeping the clay, Bindarene Flour, and polyvinyl alcohol constant) in steps of 10% between 40 and 70% solids. For these trials a fairly large batch of 70% solids adhesive was prepared as follows:

1. The clay and Bindarene flour were dry blended.

2. The blend of clay and Bindarene flour was slowly added to the proper amount of water with agitation. One half the Ahcowet was added after half the dry blend had been added. The mixture was heated by indirect means while the blend of clay and Bindarene were being added to the water, otherwise adequate mixing would not have been obtained. The temperature was raised to and maintained at 180°F. until a smooth mix had been obtained, after which the polyvinyl alcohol was added and then the urea. Following the addition of the urea the remainder of the Ahcowet was added. After thoroughly mixing, the adhesive was permitted to cool to 130°F., at which temperature it was tried on the corrugator. The adhesive as prepared above was quartered and sufficient amount of water added to each to give adhesives of 40, 50, 60 and 70% solids. The proportions used in each are shown in Table II. Following the testing of the above adhesives, the one which showed the most promise (50% solids) was used as the base for subsequent formulations in which the total solids were maintained at 50% but the proportions of clay, Bindarene flour and polyvinyl alcohol were varied plus and minus 10%. The formulations were prepared as described in Part I. The proportions used in each formulation are shown in Table III.

TABLE II

ADHESIVE FORMULATIONS VARYING PERCENTAGE SOLIDS

Formula Number	Adhesive Composition*, parts						Adhesive Characteristics			
	Water	Clay	Bindarene	Polyvinyl Alcohol	Ahcowet	Urea	Solids, %	Temperature Applied, °F.	Viscosity, seconds	Bonding Characteristics
15	195	137	286	14.8	2.2	14.8	69.7	130	**	No fiber pull at 50 f.p.m. Adhesive did not transfer very well.
16	302	137	286	14.8	2.2	14.8	59.8	130	**	Poor bond at 50 f.p.m.
17	453	137	286	14.8	2.2	14.8	49.9	130	67.0 at 129°F.	Pulled fibers at 50 f.p.m. Did not hold at higher speeds--i.e., 100 f.p.m.
18	676	137	286	14.8	2.2	14.8	40.0	130	20.0 at 129°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speed--i.e., 100 f.p.m.

* Weight basis.

** Too viscous to measure with Stein-Hall viscometer.

TABLE III

ADHESIVE FORMULATIONS VARYING AMOUNTS OF BASIC MATERIALS

Formula Number		Adhesive Composition*, parts						Adhesive Characteristics			
		Water	Clay	Bindarene	Polyvinyl Alcohol	Ahcowet	Urea	Solids, %	Temperature, °F.	Viscosity, seconds	Bonding Characteristics
19	Reference	453	137	286	14.8	2.2	14.8	49.9	130	30.0 at 129°F.	
20	Clay increased 10%	453	151	286	14.8	2.2	14.8	50.6	130	34.0 at 128°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds--i.e., 100 f.p.m.
21	Clay decreased 10%	453	124	286	14.8	2.2	14.8	49.1	130	29.5 at 130°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds
22	Bindarene increased 10%	453	137	314	14.8	2.2	14.8	51.4	130	31.5 at 129°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds
23	Bindarene decreased 10%	453	137	257	14.8	2.2	14.8	48.2	130	26.5 at 129°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds.
24	Polyvinyl alcohol increased 10%	453	137	286	16.3	2.2	14.8	49.9	130	30 at 130°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds.
25	Polyvinyl alcohol decreased 10%	453	137	286	13.4	2.2	14.8	49.9	130	26.5 at 128°F.	Pulled fiber at 50 f.p.m. Did not hold at higher speeds. Seemed brittle.

* Weight basis.

EVALUATION

The merits of the various formulations were determined by visual observation of the flow characteristics and resulting bond obtained at various corrugator speeds. It should be mentioned that a corrugating adhesive must be capable of satisfactorily bonding board at single-facer speeds of at least 450 to 500 feet per minute to be competitive.

DISCUSSION OF RESULTS

As was mentioned previously, the objective of this study was to investigate the influence of the percentage solids on the initial bonding of single-faced board fabricated with an adhesive comprised of Bindarene flour, clay and polyvinyl alcohol as the active ingredients. The study was carried out in two parts. Part I was what might be called a speculative phase in that an attempt was made to bracket the desirable formulation or to obtain a formulation which would give sufficient bonding on the single-facer to make it useful as a point of reference and a foundation on which to build.

The results obtained with the formulations tried in Part I are given in Table I together with the proportions of each ingredient in the formula. It may be observed from the data presented in Table I that none of the formulations tried in this phase were satisfactory as a corrugating adhesive. As mentioned previously, a satisfactory corrugating adhesive must be capable of bonding board at speeds in excess of 450 feet per minute and should possess a cohesive strength in excess of the fiber-to-fiber bond strength of the components. In other words, one of the characteristics of a good adhesive is its ability to pull fiber when the combined board is pulled apart. Best results were obtained with formula No. 9. With this particular formulation, satisfactory bonding was obtained at a speed of 50 feet per minute. However, when the speed was increased to 100 feet per minute the bond was unsatisfactory.

When the individual formulations are considered, it may be observed that Formulae No. 1 and 2 were prepared using a small amount of sodium aluminate. The presence of the sodium aluminate gave greater body to the adhesive, resulting in an adhesive of relatively low solids and less fluidity. Examination of the board coming off the corrugator indicated no bonding. The adhesive appeared to be too heavy to wet the board properly. Also, examination of the glue line, in Run 1 and 2, with the aid of a microscope, indicated that the adhesive was not flowing evenly and that when the adhesive came in contact with the board it behaved somewhat like popcorn in that it appeared to undergo a very mild but non-uniform puffing up or explosion. Although the percentage solids was higher (sodium aluminate lower) in Run 2, the adhesive had better spread characteristics. As may be noted, the adhesive was applied at 170°F. in contrast to 126°F. in No. 1. The bond was unsatisfactory, however, in both cases. These two runs indicated that sodium aluminate as used did not offer any advantage.

In Run No. 3 the solids content was increased to 56% and 10 parts of urea was added to increase the fluidity. The board held together at 50 feet per minute but did not pull fibers. The adhesive used in Run No. 4 behaved similarly. Formula No. 5 was a mixture of No. 3 and 4 to which a small amount of phosphoric acid was added. The results were unsatisfactory.

In Formulae No. 6 through 11, the sum of the clay and the Bindarene was kept constant. In Runs 6 through 8 the ratio of polyvinyl alcohol to Bindarene was relatively constant, as well as the percentage solids. The bonding was unsatisfactory with these three formulations. In Formulae 9 through 11 the ratio of polyvinyl alcohol to Bindarene varied widely, with the ratio in No. 10 being outside the patent and on the high side. This was purposely done to see if the use of a greater amount of polyvinyl alcohol would be advantageous. As may be seen from Table I, the results obtained with No. 9 were the best in Part I. The remaining formulations did not exhibit satisfactory bonding.

In general, the adhesive formulations appeared to lack sufficient initial bonding. In this connection, it should be mentioned that when heat is applied to these adhesives the viscosity decreases. Thus, there are two opposing forces taking part--i.e., the increase in viscosity as a result of loss of water is undoubtedly opposed by the reduction in viscosity by virtue of heat. Also, there is some question as to whether the ingredients in the proposed adhesive will yield sufficient strength for single-faced board when it is fully set. No tests have been made in regard to this and the question is raised merely as a result of cursory observation.

PART III

As discussed earlier, the formulations in Part II are merely deviations of the best formula found in Part I--namely, Formula No. 9. The work carried out in Part II may be divided into two phases. The first phase embraces Formulae 15, 16, 17 and 18. The adhesive used in these runs differed only in percentage solids. The proportions of each ingredient, percentage solids and the bonding characteristics are given in Table II. It may be observed that the best results were obtained with Formula No. 17 which contained 50% solids. At 50 feet per minute the adhesive pulled fibers; however, when the speed of the corrugator was increased to 100 feet per minute, the components were held together but there was no fiber pulled when the board was pulled apart. This particular adhesive formulation appeared to spread well and adequately wet the components. It is believed that this adhesive requires too long a period to develop initial bond. The general behavior of each of the other formulations tried in this phase was as follows:

No. 15 was made up to 70% solids. This formulation produced a very stringy adhesive which did not transfer well. When cooled to 100°F., it became thick and somewhat tacky. At 50 feet per minute corrugating speed and a 0.012-inch adhesive roll clearance the board held together as it emerged from the pressure nip; however, it easily delaminated without any pulling of fibers. It is believed that the adhesive was too thick to properly wet or penetrate the components, particularly the liner. Also, it was observed that when the adhesive got on the hot corrugating rolls it did not flake off but appeared to form a hard mass which was difficult to remove from the corrugating roll.

No. 16 was used as 60% solids. It spread better on the transfer roll than did No. 15. The board made at 50 feet per minute was held together when it came out of the corrugator; however, it could be readily pulled apart without any fiber pull. After standing about 10 minutes there was some fiber pull. Microscope examination indicated that the adhesive was not penetrating the components well enough, although better than No. 15. As in the case of No. 15, the adhesive which was transferred to the bare corrugating roll would not flake off.

As mentioned above, Formulation 17 gave the best results of the four. At 50 feet per minute, the adhesive pulled fibers when pulled apart by hand. Above this speed, however, no fiber pull was evident. As in the case of 15 and 16, the adhesive did not flake off the hot corrugating roll.

No. 18 was made as 40% solids. The viscosity at 130° was 20 seconds. At 50 feet per minute the bond was not as good as with No. 17 although some fiber pull was evident after the board was allowed to set a few minutes.

The second phase of Part II consisted in taking the best formulation found in the first phase (No. 17) and varying the proportions of each ingredient plus and minus 10% and noting the effect on the bonding characteristics. The proportions used, together with an evaluation of the bonding, may be seen in Table III.

It may be noted that in all the trials repprted in Table III there was exhibited about the same degree of bonding. That is, they all pulled fibers at 50 feet per minute. At 100 feet per minute the components were held together but were easily delaminated without pulling fibers.

SUMMARY

This study was initiated to investigate the possible application of an adhesive comprised mainly of polyvinyl alcohol and waste sulfite liquor as a bonding agent in the manufacture of corrugated board. Inasmuch as there was very little information available regarding its use as a corrugating adhesive, the approach used in this study was to try to bracket the formulation with the most desirable characteristics and then investigate the effect of varying the proportions of the reference formula.

The merits of each formulation were determined by fabricating single-faced board under normal but controlled conditions. Inasmuch as the degree of bonding was not satisfactory, no physical tests for bonding were made, rather the evaluation was carried out by visual observation of the behavior of the adhesive on the machine and examination of the board.

The results obtained with the various formulations investigated indicate the following:

1. None of the adhesive formulations tried exhibited sufficient initial bond strength to warrant their use as a corrugating adhesive.

2. Best results were obtained when the solids were approximately 50%.

3. It was found that, in the formulation which gave the best results--No. 17, the proportions of clay, Bindarene and polyvinyl alcohol could be varied ±10% without any significant effect on the degree of bonding.

4. It is believed that the question of time to develop initial bond is the biggest obstacle facing the application of the above formulations as a corrugating adhesive.

FUTURE WORK

The present study is only a cursory investigation of possible formulations. However, the results obtained to date indicate that the present formulations are a long way from being satisfactory. On the basis of comparative speeds the quality of the adhesive under study must be increased about ten-fold. Observations made during this study raise the question as to whether or not the combination of polyvinyl alcohol and Bindarene within the range specified will produce an adhesive with sufficient bond strength to be used as a corrugating adhesive. Consequently, it is suggested that consideration be given to the evaluation of this adhesive as a double-facer adhesive before continuing with work on the single-facer. Such a procedure would have a number of advantages such as

1. More time for development of bond. If a satisfactory formulation cannot be worked out for double-face adhesion, then there is no hope for its use as a single-face adhesive.

2. Provide information as to the ultimate bond strength which can be obtained.

3. Should provide a better index of progress as it is believed that such an adhesive can be used for the double-backing operation in so far as initial bond is concerned. Current results as single-face operations does not provide any useful index as to progress inasmuch as most of the formulations do not bond at any speed other than 50 feet per minute.

It may also be desirable to consider the use of polyvinyl acetate in place of the alcohol in future work. Such a substitution should permit the use of a greater quantity of acetate without upsetting the economics. In this connection, it should be pointed out that polyvinyl acetate might cause more of a problem in the reworking of the box scrap and commercial waste containing this adhesive.

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R.C. McKee

R. C. McKee, Chief, Container Section

M. F. Skalmusky /ls

M. F. Skalmusky, Technical Assistant

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